Demography, Vol. 32, No. 2, May 1995

# Educational Inequality in Adult Mortality: An Assessment with Death Certificate Data from Michigan*

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Education was added to the U.S. Standard Certificate of Death in 1989. The current study uses Michigan's 1989–1991 death certificates, together with the 1990 Census, to evaluate the quality of data on education from death certificates and to examine educational differences in mortality rates. With log-rates modeling, we systematically analyze the variability in educational differences in mortality by race and sex across the adult life cycle. The relative differences in mortality rates between educational levels decline with age at the same pace for all sex and race categories. Women gain a slightly greater reduction in mortality than men by reaching the secondary-education level, but a modestly smaller reduction by advancing beyond it. Blacks show a reduction in predicted mortality rates comparable to whites' by moving from the secondary to the postsecondary level of education but experience less reduction than whites by moving from the primary to the secondary level. Thus, the secular decline in mortality rates that generally accompanies historical improvements in education might actually be associated with an increase in the relative differences between blacks' and whites' mortality. We discuss limitations of the data and directions for future research.

Differences in adult mortality by socioeconomic status (SES) in the United States were established clearly by Kitagawa and Hauser (1973). Moreover, a number of subsequent studies point to the widening of socioeconomic differences in mortality not only in the United States but also in Great Britain (Davey Smith, Bartley, and Blane 1990; Feldman et al. 1989; Pappas et al. 1993; Rogot, Sorlie, and Johnson 1992a; Rogot et al. 1992b; Townsend, Davidson, and Whitehead 1988).

* We have shared equally in the production of this manuscript and have listed our names alphabetically. This work was funded by the Population Studies Center of the University of Michigan and by All-University Research Initiation Grant 61–6663 from Michigan State University. We thank Lori P. Wibert for research assistance and Charles B. Nam, William F. Stinner, and two anonymous reviewers for helpful comments. An earlier draft was presented at the intercongress seminar of the International Sociological Association's Research Committee 41 (Population), held in Montreal on August 24, 1993.

Fewer studies have examined whether socioeconomic differences in adult mortality (as shown, for example, through differences in death rates by educational attainment) might depend on sex and race. This lack of attention is surprising because social stratification researchers have extensively examined variation by sex and race in the benefits or returns to education for other socially valued outcomes such as occupational status and earnings (Farley and Allen 1987; Featherman and Hauser 1978; Treiman and Terrell 1975).

The purpose of this study is to fill the research gap by modeling variations in educational differences in adult mortality by sex and race with data from the State of Michigan. In compliance with the 1989 revision to the U.S. Standard Certificate of Death, Michigan became one of a large number of states to add education as an item to the death certificate and to achieve at least a 90% rate of completion on this item. Until now, however, the recency of this revision has precluded a multivariate analysis with this new source of data or an assessment of its limitations.

## CONCEPTS AND ISSUES

Research on differences in mortality by social class has a long history. In North America and Europe, the appearance of SES differentials in mortality may have coincided with the rapid economic development of the eighteenth and nineteenth centuries, when death rates fell more quickly for the middle and upper classes. These differences then diminished in the first few decades of the twentieth century, as the principal causes of death shifted from communicable diseases to the degenerative diseases associated with old age. After World War II, however, the trend toward closing the socioeconomic gap in adult mortality halted (Antonovsky 1967). Now the gap may be increasing once again, at least in the United States and Britain (Marmot and McDowall 1986; Pappas et al. 1993; Rogot et al. 1992a; Townsend et al. 1988), although at lower average levels of mortality than existed earlier in this century.

Kitagawa and Hauser's (1973) study, which linked 1960 United States Census data with a sample of 1960 death certificates, provided the first direct assessment of SES differentials in mortality for the United States. Methodologically their study helped to establish educational attainment as a principal measure in research on SES differentials in mortality. Substantively it set the stage for research on variability of SES differentials by sex and race. That analysis, however, was calculated for large age groups (25–64 and 65+) and did not test for statistical significance in the interactions between education and race or sex on the mortality ratios.

### Education as a Primary Indicator of SES

SES is a multidimensional concept for which occupation, income, and education are typical indicators. Most British researchers (e.g., Marmot et al. 1978b; Marmot, Shipley, and Rose 1984; Marmot and McDowall 1986; Susser, Watson, and Hopper 1985; Townsend et al. 1988) have relied on occupational groups to indicate social class. Kitagawa and Hauser (1973) found inverse relationships between mortality and rankings of occupation and income, but they preferred education as the primary indicator of SES because educational attainment tends to become fixed in early adulthood, whereas earnings and occupational status may change in response to changes in health. Moreover, educational attainment can be assessed for all individuals, whereas occupational status is not assessed easily for persons who have left or who have never entered the labor force.

Educational attainment is relevant to material, behavioral, and cognitive theories about the relationship of SES to health and mortality. Education has a direct effect on individuals' income-generating ability and hence on their access to adequate diet, shelter, health care services, and other material conditions that can promote a long, healthy life. Epidemiologists have found that education is related more closely to important health behaviors, such as smoking, than is either income or occupation (Winkleby, Fortmann, and Barrett 1992). Education also may enhance one's ability to use information in making decisions that improve one's life chances.

## Educational Differentials in Mortality by Sex

Kitagawa and Hauser's research suggested that in 1960, the returns to longevity from education were generally greater for women than for men. Among whites age 25–64, the larger educational differentials in mortality ratios for women were due primarily to relatively high levels of mortality among women with fewer than five years of schooling (1973:12). Although educational contrasts in mortality ratios diminished at older ages for both men and women, the most striking persistent contrast was a marked inverse association between mortality and education level among white women after age 65 (Kitagawa and Hauser 1973:13). At ages 65 and older, educational differences were practically nonexistent among older white men and among nonwhites of both sexes.

More recent studies suggest that some of the patterns observed by Kitagawa and Hauser may have changed. Using Kitagawa and Hauser's findings and data from the National Health and Nutrition Examination Survey-Epidemiologic Followup Study (NHANES-EFS), Feldman and his colleagues (1989) found that an educational difference in mortality had emerged during the 1970s for middle-aged (i.e., ages 55–64) and older white adult males.[1] One important reason for this new trend was a constancy in heart-disease mortality rates among the least educated men, coupled with an increasingly sharp decline in heart-disease mortality among men with more education (Feldman et al. 1989:923). Because smoking is a risk factor for heart disease, the authors (1989:927–28) noted that more highly educated smokers were more likely to stop smoking after their first interview in this longitudinal survey.[2]

Further evidence of changes in educational differentials in mortality by sex was offered by Rogot et al. (1992a) in their analysis of data from the National Longitudinal Mortality Survey (NLMS) for 1979–1985. They concluded that socioeconomic differentials in mortality are slightly larger for men than for women when viewed in terms of remaining life expectancy at various adult ages for the least educated persons, in contrast with the most educated.[3]

Pappas and his colleagues (1993) used deaths reported in the 1986 National Mortality Followback Survey (NMFS) and national estimates of income and education groups in the 25-to-64 year age range based on the 1986 National Health Interview Survey (NHIS) to examine differentials in mortality by SES. The authors not only concluded that socioeconomic differentials in mortality had increased since 1960, but also reported a larger educational differential in mortality for white men than for white women. The age-adjusted mortality ratio for white men with 11 years or fewer of schooling in 1986 was 2.5 times as great as for men with four or more years of college. The difference among women was only 86% (1993:105). The authors did not comment on the strength of this relationship for black males as compared with black females.

Together these studies imply that current educational differentials in mortality are somewhat larger for men than for women; this point suggests that men benefit more than women from improved levels of education. This conclusion, however, is typically based on comparisons of mortality at the lowest and the highest ends of the educational continuum.

Increments in education may not favor males or females uniformly. Comparisons of mortality at successive educational levels (e.g., primary versus secondary, secondary versus postsecondary) may show that some increments in education are associated with greater reductions in mortality for women, while other increments lead to greater mortality reductions for men.

## Educational Differentials in Mortality by Race

Some social stratification researchers have found that the returns to education are different for blacks than for whites for certain social outcomes. Featherman and Hauser (1978), for example, reported that white males received a larger return in earnings for each year of elementary and secondary schooling than did black males, whereas the returns on years of postsecondary education were comparable for black men and for white men.

Yet the findings on the racial disparity in the returns to education in the form of longevity are limited and conflicting. Although Kitagawa and Hauser analyzed educational differences for nonwhite males and females in 1960, they did not compare the sizes of educational differences in mortality for nonwhites and for whites. Moreover, the educational categories for the two groups were not strictly comparable. Data limitations restricted the analyses for nonwhites to fewer educational categories because of the small number of nonwhites with more than a high school education.

Until recently, Kitagawa and Hauser's work was one of the few nonecological assessments of the educational gradient of mortality for a minority population.[4] In a contemporary report based on linked data from the 1986 NHIS and the 1986 NMFS, Rogers (1992) announced a significant difference between blacks and whites in the effect of SES, as measured by income, on mortality, but he dismissed the result without much discussion (1992:296). With the same data set, Pappas et al. (1993) reported an inverse relationship between education and mortality ratios for blacks that was similar for whites at ages 25–64. Unfortunately they did not report tests for racial differences in the strength of that relationship. In addition, neither of these analyses included individuals age 65 and older.

These problems did not beset the work of Elo and Preston (1994), who used the NLMS to analyze how educational differences in the odds of dying depended on race, sex, and age. They found a statistically significant inverse relationship between education and the odds of dying between 1979 and 1985 that was larger for men than for women, and larger for persons age 25–64 than for persons age 65–89. Furthermore, they found that the effects of education on mortality were much the same for blacks and for whites. The sex difference was interpreted to reflect the greater effect of men's than of women's schooling on income, together with men's greater control over the family budget in many households. The stronger influence of education on the mortality of those age 25–64 than of elderly adults was thought to show that current income was a more sensitive proxy for the material returns to education for persons of labor force age than for persons of retirement age. In short, Elo and Preston's work made it credible that the differences in inverse effects of SES (especially education) on mortality may have widened for all race and sex groups, even at ages 65 and over, in the decades after Kitagawa and Hauser's study.

## Objectives

The above-cited studies show that current educational differences in mortality are somewhat larger for men than for women, but this conclusion is usually based on comparisons of mortality at the extremes of the educational continuum. Successive comparisons at more than two educational levels (e.g., primary versus secondary, secondary versus postsecondary) may show that educational differences in mortality by sex, race, or age vary inconsistently across the continuum. The current investigation employs a data set and a statistical methodology (discussed below) to overcome this limitation in order to explore the following questions:

Do educational differences in adult mortality vary between males and females?
Do educational differences in adult mortality vary between blacks and whites?
Do educational differences in mortality diminish with age? If they do so, to what extent and how rapidly do they diminish, and is this pattern similar across race and sex?

This exploration uses a more recent data set on mortality than that employed by Rogot et al. (1992a), Pappas et al. (1993), or Elo and Preston (1994).

# METHODOLOGY

## Data Sources

Mortality in this study is measured by age-, sex-, race-, and education-specific death rates. Michigan's 1989–1991 death certificates for state residents who were age 25 or older at the time of their death provide the numerators for these death rates.[5] Because the 1990 Census was conducted roughly at the midpoint of this three-year period, the denominators are estimated from the 5% Public Use Microdata Sample (PUMS) of the 1990 Census for the State of Michigan.[6]

The aggregation of three years of death certificates dampened secular fluctuations in death rates and provided a total of 226,033 cases of death to Michigan residents age 25 or older. Information on education, sex, and race was complete for 96.2% of these records. We used hotdecking procedures to impute valid codes for records with missing data on any one of the three variables; the resulting number of usable records for this study was 224,470. This number represented 99.3% of the total cases.[7]

The large number of deaths on which to base our analysis gave us an advantage over previous research (e.g., Feldman et al. 1989; Kitagawa and Hauser 1973; Rogot et al. 1992a, 1992b). Kitagawa and Hauser, for example, were able to match 62,405 death certificates registered between May and August 1960 to 1960 Census questionnaires. The size of their sample, however, proved insufficient to prevent problems of reliability, as footnoted throughout their study (e.g., Kitagawa and Hauser 1973: 12,15,17,76,77). This was particularly true for their analysis of the nonwhite population. Longitudinal studies (e.g., NHANES-EFS, the Alameda County Study, and the Framingham Heart Study) and those based on linking administrative records with other survey data typically encounter such sample-based restrictions with respect to age, race, or both (Feinleib 1983; Feldman et al. 1989; Haan, Kaplan, and Camacho 1987).

## Data Quality

The recent availability of an education item on the death certificates necessitates an evaluation of its quality. In particular, the completion of a high school or a college education is likely to be overreported, while the failure to finish high school or college is probably underreported. Lacking a direct means of testing for such misreporting, we compared the age-standardized mortality rates across five education categories: a primary education or less (0–8 years), some secondary education (9–11 years), a high school education (12 years), some postsecondary education (13–15 years), and a college education (16 or more years)(see top panel of Table 1). For each of the four race/sex subpopulations, the death rates for those who completed high school are greater than for those with only some secondary education. Similarly, the death rates for those who completed four or more years of college are greater than for those with a less complete postsecondary education. These are precisely the patterns one would expect to find as a result of overreporting the completion of either a high school or a college education.

To minimize the biases introduced by this type of educational misclassification, we recategorized educational attainment into three broader groups: a primary education or less, a secondary education (9–12 years), and a postsecondary education (13 or more years of school)(see lower panel of Table 1). In three of the four race-sex groups, mortality rates decrease monotonically from primary to postsecondary education, as one would expect. The exception occurs for African-American men, whose age-standardized death rates are slightly higher at nine to 12 years of education than at eight or fewer years. Therefore the collapsed educational groupings appear to minimize the problem of misclassification of decedents' educational attainment on death certificates.

The denominators for this analysis were taken from estimates of the population provided by the 5% Public Use Microdata Sample (PUMS) of the 1990 Census of Michigan. These estimates are subject to sampling errors and to errors in coverage in overall census counts. Errors in coverage result most often in a net underenumeration of the population. The consequence of underenumeration is to bias the estimated death rate upward. This bias will be greater for the subgroups in which underenumeration is higher: males, blacks, younger adults, and less highly educated people (Fein 1990; Passel, Siegel, and Robinson 1982; Siegel 1974). This bias was also present in the mortality rates calculated by Kitagawa and Hauser (1973), but it is weaker in the rates analyzed here because of reductions in the net errors of coverage between the 1960 and the 1990 Censuses.[8]

Table 1. Age-Standardized Education-Specific Death Rates by Race and Sex: Michigan Residents, 1989–1991[a]

| | Detailed Education Categories | | | | |
|---|---|---|---|---|---|
| | Primary | 9–11 Yrs | 12 Yrs | 13–15 Yrs | 16+Yrs |
| White Males | 18.7 | 12.3 | 18.0 | 9.4 | 10.6 |
| Black Males | 20.4 | 16.6 | 31.3 | 12.3 | 15.3 |
| White Females | 16.6 | 8.5 | 15.2 | 9.7 | 10.8 |
| Black Females | 15.0 | 10.1 | 19.3 | 8.9 | 22.2 |

| | Collapsed Education Categories | | |
|---|---|---|---|
| | Primary or Less (< 9 Years) | Secondary (9 to 12 Years) | Postsecondary (13+ Years) |
| White Males | 18.7 | 14.8 | 9.9 |
| Black Males | 20.4 | 21.5 | 13.1 |
| White Females | 16.6 | 11.9 | 10.1 |
| Black Females | 15.0 | 13.5 | 11.0 |

[a] Death rates for each race-sex group are standardized by the age distribution for that group's population.

## Analytic Strategy

Whereas previous research has examined educational differences in mortality by comparing age-standardized mortality ratios, a more rigorous comparative strategy is to model educational differences in mortality rates over the life cycle. Hence we examine educational differences in mortality by fitting a log-rates model computed with the GLIM statistical software. The model is expressed in terms of expected numbers of deaths (D) for a subpopulation with a given number of person-years of exposure (N). The general logarithmic form of the model is:

$$\log E(D_{ijkl}) = \log N_{ijkl} + \log u_{ijkl},$$

where *i*, *j*, *k*, and *l* denote respectively an age, a race, a sex, and an education category. The first term on the right-hand side of the equation is the natural logarithm of the size or person-years for the subpopulation at risk. The second term is the natural logarithm of the underlying hazard or mortality risk; this is the focus of the model building. (For further discussions and examples of log-rates models, see Agresti 1990; Hu and Goldman 1990; and Xie 1989 and 1990.)

We use tests of significance to select the most parsimonious model to represent educational differences in mortality by age, race, and sex. Rafferty (1986) argued that the likelihood-ratio test (LRT) is ill-suited to the task of model selection with large samples. When the sample is large, the LRT is likely to lead one to conclude that even the smallest of differences between models is statistically significant. To avoid this problem, Rafferty recommended the use of the BIC statistic, originally derived from a Bayesian approach to statistical inference:

$$\mathrm{BIC} = L^2 - (\mathrm{df}) \log N,$$

where $L^2$ is the likelihood-ratio chi-square test statistic, df represents the degrees of freedom, and N is the total sample size. The value of BIC can be either positive or negative. In deciding among several models, the preferred model is the one with the lowest BIC value. The BIC provides a consistent model-selection procedure in that it chooses the correct model with high probability (Rafferty 1986).

# RESULTS

## Model Identification

Model 1 in Table 2 is the starting point, or baseline, for analyzing educational variation in mortality rates. This model permits one to fit exactly the age-race-sex-specific mortality rates (i.e., all first-order and higher-order interactions among age, race, and sex are included in the model) while assuming that there is no effect of education on mortality. In this model, age is measured categorically by 13 five-year age groups ranging from 25–29 to 85 and over. Race includes separate categories for black and for white residents. Sex includes separate categories for female and for male residents. The model has a log-likelihood ratio of 11,563 with 104 degrees of freedom and a BIC statistic of 10,282. Any model with a lower BIC statistic represents an improvement over the baseline model.

Model 2 adds to the baseline model a main effect for education that permits the mortality rates to differ for residents with primary, secondary, and postsecondary education. This model is clearly an improvement over the baseline, as represented by a substantially lower BIC statistic of 3,318. This model assumes, however, that the effect of education on mortality is constant across age, race, and sex.

Model 3 includes interaction terms that permit the effect of education on mortality to

Table 2. Modeling Educational Differentials in Mortality Rates by Race, Sex, and Age in Michigan, 1989–1991 (N = 224,470)

| Model | Scaled Deviance | DF | BIC |
|---|---|---|---|
| 1. Baseline | 11,563 | 104 | 10,281.56 |
| 2. Main Effect for Education | 4,575 | 102 | 3,318.31 |
| 3. All Two-Way Interactions | 361 | 94 | −797.13 |
| a. Race x education | 879 | 96 | −304.34 |
| b. Sex x education | 549 | 96 | −633.56 |
| c. Age x education | 604 | 96 | −579.13 |
| d. $(Age)^2$ × education | 429 | 96 | −753.56 |
| 4. Major Three-Way Interactions | 300 | 88 | −784.65 |
| a. Race × sex × education | 315 | 90 | −794.36 |
| b. Race × age × education | 315 | 90 | −793.98 |
| c. Sex × age × education | 336 | 90 | −772.94 |

The baseline model fits the race-sex-age-specific mortality rates exactly, using 13 categories for quinquennial age groups (25–29, 30–34, . . . 85 and older) and two categories each for the sex and race (white and black) variables. A continuous measure of age is used in the second- and higher-order interactions with education. Because the analysis is restricted to adults, age is defined as the number of years over age 25. Although not shown in the above table, the addition of interactions with age squared in the three-way interaction model did not improve the fit of the model beyond that of the major three-way interaction terms.

vary by race, sex, and age. The interaction of education with sex and race allows for a unique effect of education on the mortality rates of women as compared with men, and of blacks as compared with whites. Whereas 13 categories of age are used in the baseline portion of this model, the interaction of education with age relies on two parameters: an interaction of education with a continuous measure of age, and an interaction of education with an age-squared measure.[9] These two interaction terms provide a test for a nonlinear shift in educational differences in mortality with respect to age.

The improvement of Model 3 over Model 2 is shown by the decrease in the BIC statistic to -797. Not all of the interactions, however, may be statistically significant. Tests of statistical significance based on a backward selection procedure are used to determine whether this is the case. In Models 3a to 3d, one of the second-order interaction terms involving education is deleted from Model 3, but each BIC for Models 3a to 3d is larger than that for Model 3. In other words, the statistical fit of Model 3 is diminished significantly by the deletion of any of the two-way interaction terms involving educational attainment.

Model 4 and the subset of Models 4a to 4d test the statistical significance of third-order interactions to determine whether an even more complex model is needed to compare educational variation in mortality by age, race, and sex. Because none of these models results in a lower BIC than reported for Model 3, it is evident that Model 3 provides the best-fitting and most parsimonious model. Thus Model 3 is the basis for the findings reported below.

## Education-Related Variation in Mortality by Age, Sex, and Race

The education-related variation in mortality rates based on the main effects model (Model 2) and the two-way educational interaction model (Model 3) shows the relative (not the absolute) differences in mortality. Model 2 shows that even after controlling for the main effects of race, sex, and age on the mortality rates of Michigan adult residents, the mortality rate of those with only a primary education is 15% higher than the rate of those with only a secondary education ($e^b$ = 1.153; Table 3, Col. 2). In turn, those with a secondary education have a mortality rate 46% higher than that of the more highly educated ($e^b$ = 1.464; Table 3, Col. 2). Thus it appears that an increase in the prevalence of postsecondary schooling will lower the death rate more than will a reduction in the prevalence of high-school dropouts.

## Interactions of Age with Education

The differences in mortality rates by level of education depend on age, however. The age-specific mortality rates of the primary-educated versus the secondary-educated population diminish by about 2.5% ($e^{-0.0249}$ = 0.975; Table 3) for each year over age 25. Because of the statistically significant ($p < 0.05$) age-squared term shown in Table 3, the decrease in the effect of advancing age on mortality is not linear, but rather proceeds along a gradually sloped trajectory (Figure 1). On the other hand, the mortality rates of the secondary-educated versus the postsecondary-educated population fall by somewhat less than 2% ($e^{-0.0171}$ = 0.983; Table 3) for each year over age 25 and do not appear to decelerate with increasing age (Figure 2). Thus the inverse effect of education on rates of mortality diminishes with age, but this weakening is less noticeable at the higher levels of education.

## Interactions of Race with Education

Featherman and Hauser (1978) observed that whites received larger returns to elementary and secondary schooling than blacks in the form of earnings but that blacks and

Table 3. Education-Related Contrasts in Mortality Rates from Log-Rates Models

| | Main Effects Model (2) | | 2-Way Interactions Model(3) | |
|---|---|---|---|---|
| Contrast | b | $e^b$ | b | $e^b$ |
| Main Effects of Education: | | | | |
| Primary versus Secondary | 0.1427 | 1.153 | 0.9298 | 2.534 |
| Secondary versus Postsecondary | 0.3811 | 1.464 | 1.1210 | 3.068 |
| Primary versus Secondary Interaction with: | | | | |
| Race (=Blacks) | | | −0.3220 | 0.725 |
| Sex (=Males) | | | −0.1052 | 0.900 |
| Age | | | −0.0249 | 0.975 |
| Age$^2$ | | | 0.0002 | 1.0002 |
| Secondary versus Postsecondary Interaction with: | | | | |
| Race (=Blacks) | | | −0.0318* | 0.969 |
| Sex (=Males) | | | 0.1420 | 1.153 |
| Age | | | −0.0171 | 0.983 |
| Age$^2$ | | | −0.00003* | 1.000 |

* Coefficient not statistically significant at $p < 0.05$.

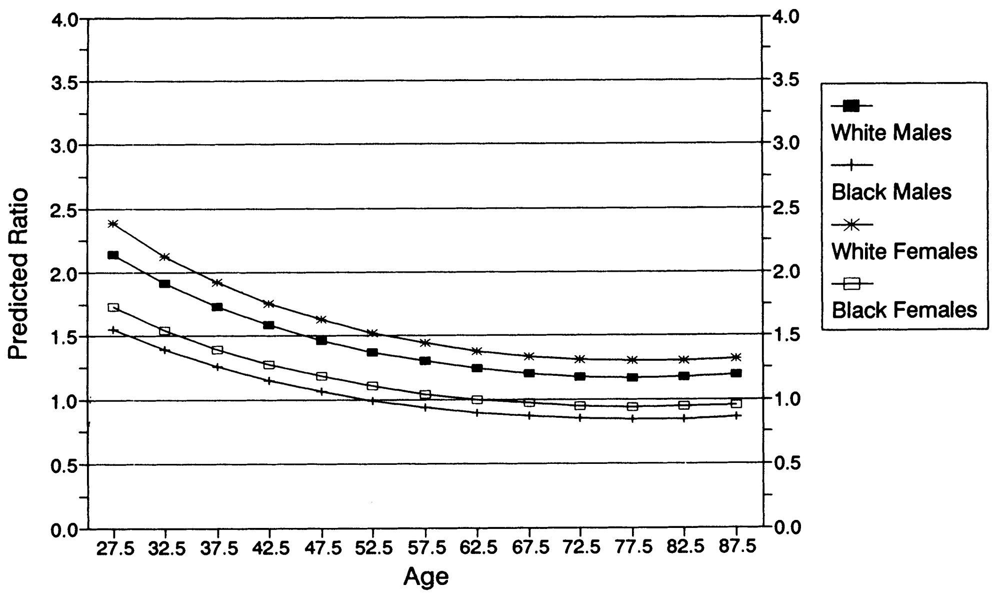


Figure 1. Predicted Primary versus Secondary Educational Mortality Ratios by Age, Race, and Sex

whites received similar earnings per year of postsecondary schooling. Higher earnings help to reduce mortality by improving one's ability to purchase health care and/or a healthier lifestyle. Thus Featherman and Hauser's work is congruent with our finding that educational differences in mortality between blacks and whites occurred only at the lower levels of schooling. In particular, we found that the mortality ratio for the primary-educated versus the secondary-educated blacks is only about three-quarters of this ratio for whites ($e^{-0.322}$ =

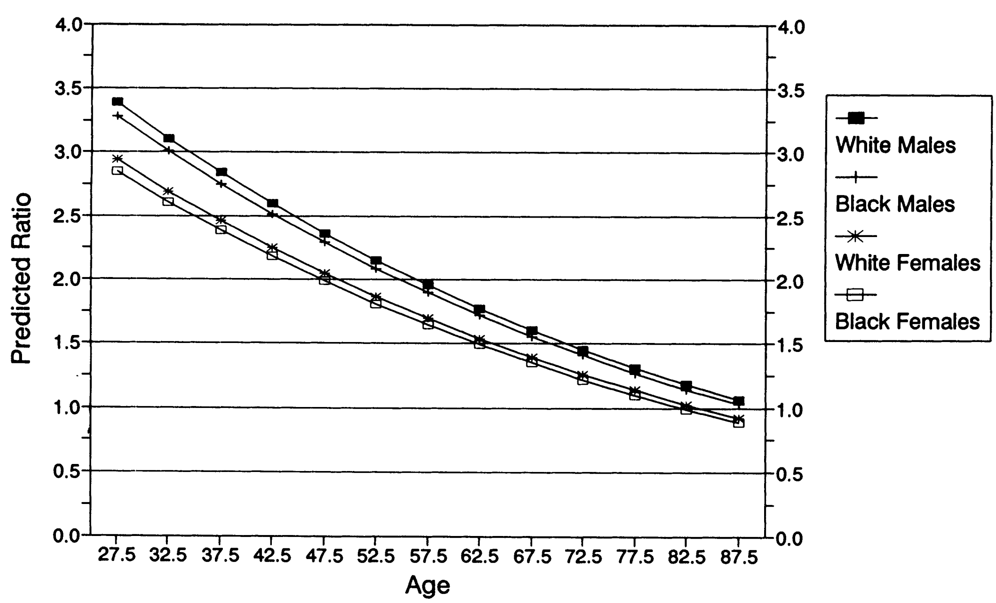


Figure 2. Predicted Secondary versus Postsecondary Educational Mortality Rarios by Age, Race, and Sex

0.725; Table 3). We found, however, that blacks and whites experienced a similar reduction in mortality by advancing from secondary to postsecondary schooling. (Note the lack of a statistically significant interaction for this contrast in Table 3.)

The education-specific ratios of black-to-white mortality rates predicted under Model 3 are shown separately for males (Figure 3) and females (Figure 4). Although racial differences in mortality diminish with age within each level of education, it is only among those with a primary education or less that we find a crossover from higher-black-than-white mortality to lower-black-than-white mortality. (This crossover is signaled by a ratio that falls below unity.) The racial crossover occurs around age 75 among males (Figure 3) and closer to age 80 among females (Figure 4). No racial crossover occurs among persons with a secondary or a postsecondary level of schooling. These findings imply that the succession of cohorts to old age should eliminate the racial crossover because smaller proportions of the elderly in the future will have only a primary education.

## Interactions of Sex with Education

The effect of education on adult mortality also depends on sex. Moving from a primary to a secondary level of education reduces the mortality rate by a factor that is 10% lower for men than for women ($e^b$ = 0.900; last column, Table 3). Moving from a secondary to a postsecondary level of education, however, reduces the mortality rate by a factor that is 15% greater for men than for women ($e^b$ = 1.153; last column, Table 3). In other words, women derive greater survival benefits than men from obtaining a secondary education (Figure 1), but men derive larger survival benefits than women from obtaining some postsecondary schooling (Figure 2). Thus, in the increase in educational attainment across the whole spectrum from primary to postsecondary levels, men gain a small net advantage in mortality decline. This male advantage is consistent with the reports from Feldman et al. (1989) and Elo and Preston (1994), but is unimpressive. It implies that the overall sex

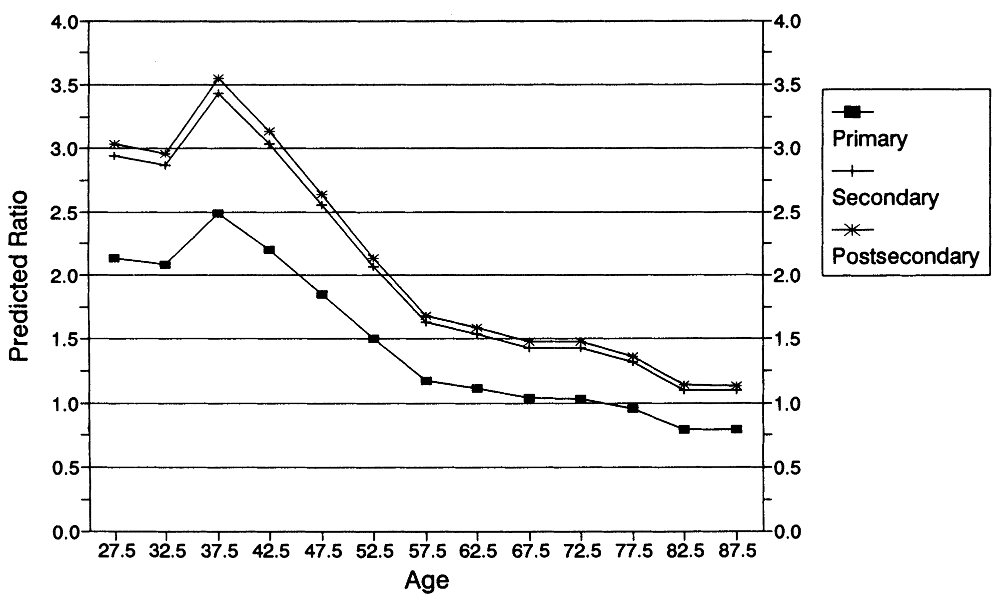


Figure 3. Predicted Black versus White Mortality Ratios for Males by Age and Level of Education

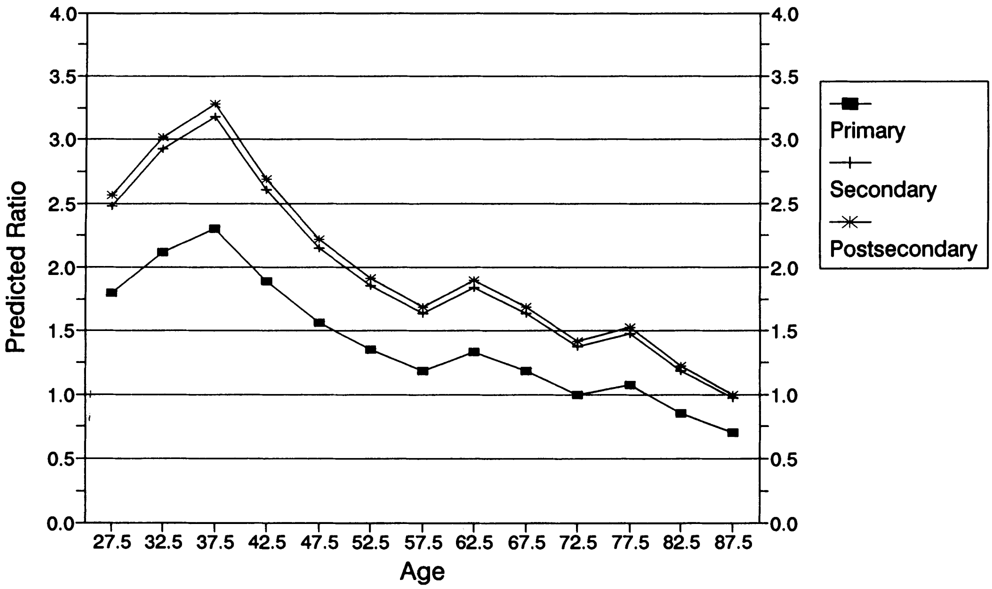


Figure 4. Predicted Black versus White Mortality Ratios for Females by Age and Level of Education

differences in mortality can be expected to decrease slightly with an increase in the proportion of Michigan's adult population with some postsecondary education.

## DISCUSSION

This study is among the first to analyze age-sex-race-education-specific rates of mortality for which education is taken from death certificates. Using three years of Michigan death certificate data, we demonstrate here that sample size problems in analyses of educational differences in mortality, such as those encountered by Kitagawa and Hauser, among others, can be minimized by taking advantage of the recent addition of education to the death certificate. An assessment of the quality of the data, however, suggested an exaggeration of years of completed schooling associated with receipt of a diploma. Thus we advise researchers to use broad educational categories to minimize this problem. Despite this limitation, the analyses in this study provide insights into the effects of education on mortality and on its variations by sex and race over the life cycle.

The current analysis showed that movement from primary to secondary schooling reduced mortality rates 10% more for women than for men but that movement from secondary to postsecondary schooling reduced mortality rates 15% more for men than for women. That is, women appear to benefit slightly more from improvements in levels of elementary and secondary schooling, whereas men benefit more from postsecondary schooling. These relationships suggest that schooling is converted into earnings at a lower rate by highly educated women than by similar men, who then can invest some of these earnings in healthier lifestyles. Indeed, the ratios of female-to-male earnings deteriorate with age, and more so among those with college degrees (Bianchi and Spain 1986:175).

Similarly, the smaller inverse effects of elementary and secondary education on blacks' mortality rates than on whites' might be explained by blacks receiving less income return on their secondary education (see Featherman and Hauser 1978). As a result, blacks would be less able to obtain the material resources (e.g., safe occupations or houses or automobiles) or services (health care) that promote long-term health.

Among elderly persons with only primary schooling, we saw a crossover from higher black than white mortality to lower black than white mortality. A puzzle for future researchers is whether this crossover signifies the selection of only the most robust blacks for survival to extreme old ages (see Manton, Poss, and Wing 1979) or the tendency to overstate the ages of lesser-educated elderly blacks (see Coale and Kisker 1986). In the current study we cannot choose between these competing interpretations. Yet if the crossover is real, we should be able to observe it for the medical causes of death common among the oldest old. Manton et al. (1979) found a racial crossover in mortality from ischemic heart disease, but they lacked the data to analyze it within categories of educational attainment. Therefore future researchers should explore education-specific racial crossovers in mortality from common degenerative diseases.

The present research holds implications for epidemiological transition theory. The decline in the mortality rate in the United States during the past century has occurred through a change from the acute infectious diseases to the chronic degenerative diseases as the leading causes of death. Although this shift has increased life expectancies more for the young than for the old, more for females than for males, and more for whites than for nonwhites (Omran 1977), the present study shows that it has not eliminated educational differences in mortality, which apparently have widened in recent decades (Feldman et al. 1989; Pappas et al. 1993). Riley (1990) noted that in a developed society, the postponement of the average age at death to a late point in the life cycle has changed both the incidence and the duration of illness. Future research therefore should investigate how and why education is related to death from specific chronic diseases. Does an inverse relationship imply the reduction or delay in the incidence of a certain disease among the more highly educated, or does it mean only that the more highly educated survive longer after onset? Such investigations should take into account not only the presence of a specific chronic disease as the underlying cause but also the frequency of its total mentions on the death certificate. Indeed, if the better educated die later, they may be at greater risk than the lesser educated of dying from an accumulation of interacting chronic conditions. This possibility then might explain the diminution of educational differences in mortality in old age.

## ENDNOTES

[1] The inverse gradient between education and mortality for middle-aged and older females was unaltered during this period.

[2] Similarly, the Whitehall Study found that the increasing disparity in mortality rates between the working classes and the middle and upper classes in England and Wales in 1931–1971 resulted partly from a growing concentration of deaths from coronary heart disease in the working classes (Marmot et al. 1978a). Two explanations were hypothesized and confirmed for this trend. One is that the indices of cigarette consumption over the period 1951–1971 remained constant in the two lowest classes but declined sharply in the two highest classes so as to increase the social class disparity in cigarette consumption. The other is that a measure of sugar consumption in the highest household-income category relative to the lowest two household-income categories fell progressively from a level above unity in 1951 to 0.75 in 1971.

[3] Elo and Preston (1994) made a similar observation about mortality rates when estimating a logistic regression model with the same NLMS data as used by Rogot and his colleagues.

[4] For examples of ecological studies see Pendleton and Chang (1978) and Potter (1991).

[5] We focus on educational differences in mortality at ages 25 or older because the level of educational attainment tends to become stable early in adulthood. This focus is consistent with the work by Kitagawa and Hauser (1973).

[6] The exact midpoint of the 1989–1991 time period is June 30, 1990. The 1990 Census was taken on April 1, 1990.

[7] We created a reference file from all death certificates containing legitimate codes on year of death, Michigan county of residence, age, race, sex, and education. Cases with a missing value on race, sex, or education were assigned a value for the missing variable corresponding to the value in a randomly selected reference case that matched the missing value case on the other five characteristics. As a result of this hotdecking procedure we retained 7,012 records that otherwise would have been excluded from the analysis: education was imputed for 6,873 cases, sex for 40 cases, and race for 99 cases.

The post-hotdecked mortality rate calculated across all subcategories was significantly higher than the pre-hotdecked rate (36.31 vs. 33.44 deaths per 1,000; $t=-6.07$; $p < 0.001$). Post-hotdecked mortality rates were significantly higher for the following subcategories: black males with 9–11 years of education, black females with 13–15 years of schooling, and white males with 9–11 years of schooling. Therefore, in the absence of hotdecking, the death rates in these subcategories would have been understated.

[8] The national rates of net underenumeration were estimated to be lower for the 1990 United States Census than for the 1960 or the 1970 Census, but higher than for the 1980 Census (Passel 1991). Estimates of underenumeration by sex, race, and age for the 1990 Census have been made only at the national level, and estimates of underenumeration by education are not available. Therefore this analysis has not attempted to adjust the data for underenumeration.

[9] The continuous age variables are based on the midpoints of the 13 five-year age categories (e.g., 27.5, 32.5). For the oldest age group (85 and above), we used 87.5 years.

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